IV. OVERVIEW OF HAZARDS AND VULNERABILITIES

This section provides a general overview of how a number of natural hazards impact Concord. The next section provides more detail about impacts at specific locations and existing mitigation efforts.

Overview of Hazards and Impacts

The 2004 Massachusetts Hazard Mitigation Plan provides an overview of natural hazards in Massachusetts. It indicates that Massachusetts is subject to the following natural hazards (listed in order of frequency): floods, heavy rainstorms, nor'easters, coastal erosion, hurricanes, tornadoes, urban and wildfires, drought and earthquakes.

Table 6 summarizes the hazard risks for the state and notes where risks in Concord differ from the state assessment. The state analysis takes into account the frequency of the hazard, historical records and variations in land use. An explanation of the definitions used can be found at the end of the table. Table 7 lists those federal disaster and emergency declarations for Middlesex County.

Table 6: Frequency and Severity of Natural Hazards in the State

Hazard	Frequency in State	Severity in State	Issues in Concord
Flood	High	Serious to extensive	Same as state
Dam Failure	Low	Extensive	Same as state
Hurricanes	Medium	Extensive to catastrophic	Same as state
Severe Storms (wind, hail, lightning)	Medium	Serious	Same as state
Tornadoes	Medium	Extensive to catastrophic	Not a major issue in Concord
Winter Storms	High	Serious	Same as state
Earthquakes	Low	Catastrophic	Not a major issue in Concord
Landslides	Low	Minor	Not a major issue in Concord
Brush Fires	Medium	Serious	Not a major issue in Concord

Definitions Used in the Commonwealth of Massachusetts State Hazard Mitigation Plan

Frequency
- Very Low Frequency: Events that occur less frequently than once in 1,000 years (less than 0.1% per year).
- Low Frequency: Events that occur from once in 100 years to once in 1,000 years (0.1% to 1% per year).
- Medium Frequency: Events that occur from once in 10 years to once in 100 years (1% to 10% per year).
- High Frequency: Events that occur more frequently than once in 10 years (greater than 10% per year).

Severity
- Minor: Limited and scattered property damage; no damage to public infrastructure (roads, bridges, trains, airports, public parks, etc.); contained geographic area (i.e., 1 or 2 communities); essential services (utilities, hospitals, schools, etc.) not interrupted; no injuries or fatalities.

- Serious: Scattered major property damage (more than 50% destroyed); some minor infrastructure damage; wider geographic area (several communities); essential services are briefly interrupted; some injuries and/or fatalities.
- Extensive: Consistent major property damage; major damage to public infrastructure (up to several days for repairs); essential services are interrupted from several hours to several days; many injuries and fatalities.
- Catastrophic: Property and public infrastructure destroyed; essential services stopped, thousands of injuries and fatalities.

Table 7: Disaster and Emergency Declarations for Middlesex County

ID Number	Type	Date
1701	Severe Storms and Inland and Coastal Flooding	April 15-25, 2007
1642	Severe storms, flooding	May 12, 2006 (continuing)
1614	Severe storms, flooding, landslides, mudslides	October 7 - 16, 2005
1512	Severe winter storms	April 1, 2004 through April 30, 2004
3191	Snowstorm	December 5 – 6, 2003
3175	Snowstorm	February 17-18, 2003
3165	Blizzard	March 2001
1364	Severe storms, flooding	March 5, 2001 through April 16, 2001
1224	Heavy rain, flooding	June 13 to July 6, 1998
1142	Heavy rain, flooding	October 1996
1090	Blizzard	January 1996
3103	Blizzard	March 1993
920	Storm	October 1991
914	Hurricane (Bob)	August 1991

Sources: www.fema.gov and *State Hazard Mitigation Plan*, MEMA and DCR, October 2004.

Flood-Related Hazards

Flooding was the most prevalent natural hazard identified by local officials in Concord. Flooding can occur during hurricanes, nor'easters, severe rainstorms and thunderstorms.

There have been a number of major rain storms that have resulted in significant flooding in eastern Massachusetts over the last fifty years. Excluding hurricanes, significant rain storms include:

- August 1954
- March 1968
- January 1979
- April 1987
- October 1991 ("The Perfect Storm")

- October 1996
- June 1998
- March 2001
- April 2004
- October 2005
- May 2006
- April 2007

Through October 2007, Concord property owners filed a total of 37 losses with the National Flood Insurance Program. Of these, 26 have been paid for a total of just over $167,600. FEMA maintains a database on these flood insurance policies and claims, which can be found at www.fema.gov/business/nfip/statistics/pcstat.shtm. The following table provides further detail from the database:

Table 8: Flood Insurance Policies and Claims in Concord (as of October 31, 2007)

Flood insurance policies in force	123
Coverage amount of flood insurance policies	$29,326,300
Premiums paid	$131,348
Total losses (all losses submitted regardless of the status)	37
Closed losses (Losses that have been paid)	26
Open losses (Losses that have not been paid in full)	0
CWOP losses (Losses that have been closed without payment)	11
Total payments (Total amount paid on losses)	$167,626.27

As defined by the Community Rating System (CRS) of the National Flood Insurance Program (NFIP), a repetitive loss property is any property for which the NFIP has paid two or more flood claims of $1,000 or more in any given 10-year period since 1978. The state plan indicates that Massachusetts is one of the 10 states that cumulatively account for 76% of all repetitive loss buildings in the United States. There are 2 repetitive loss structures in Concord (see maps in Appendix A). For more information on repetitive losses see http://www.fema.gov/nfip/replps.shtm.

Wind-Related Hazards

Wind-related hazards include hurricanes and tornadoes as well as high winds during severe rainstorms and thunderstorms.

The region has been impacted by hurricanes throughout its history, starting with the Great Colonial Hurricane of 1635. The eye of one hurricane passed right through Boston in 1944. Between 1858 and 2000, Massachusetts has experienced approximately 32 tropical

storms, nine Category 1 hurricanes, five Category 2 hurricanes and one Category 3 hurricane. This equates to a frequency of once every six years. Hurricanes that have occurred in the region include[1]:

- Great New England Hurricane* September 21, 1938
- Great Atlantic Hurricane* September 14-15, 1944
- Hurricane Doug September 11-12, 1950
- Hurricane Carol* August 31, 1954
- Hurricane Edna* September 11, 1954
- Hurricane Hazel October 15, 1954
- Hurricane Diane August 17-19, 1955
- Hurricane Donna September 12, 1960
- Hurricane Gloria September 27, 1985
- Hurricane Bob August 19, 1991

*Category 3.

Not included in this list is the Portland Gale of November 26-28, 1898, which may well have been the most damaging coastal storm in Massachusetts history.

As shown in Map 5 in Appendix A, one tropical storm has tracked through Concord. A hurricane or storm track is the line that delineates the path of the eye of a hurricane or tropical storm. The town does experience the impacts of the wind and rain of hurricanes and tropical storms regardless of whether the storm track passed through the town. The hazard mapping also indicates that the 100 year wind speed is 110 miles per hour. No tornados have been recorded within the town.

Winds during other storms also can cause damage. Downed trees and limbs can be a problem due to weather conditions such as strong wind or heavy snow and ice. Tree limbs can down power and communication lines and impact major roadways.

Winter-Related Hazards

In Massachusetts, northeast coastal storms known as nor'easters, occur one to two times per year. Winter storms are a combination of hazards because they often involve wind, ice, flooding and snow fall. The average annual snowfall for most of the town is 48 – 72 inches.

As expected, a number of public safety issues can arise during snow storms. Impassible streets are a challenge for emergency vehicles and affect residents and employers. Snow-covered sidewalks force people to walk in streets, which are already less safe due to snow, slush, puddles and ice. Large piles of snow can also block sight lines for drivers, particularly at intersections. Not all residents are able to clear their properties, especially the elderly. Refreezing of melting snow can cause dangerous roadway conditions.

[1] Information on storms provided by Cambridge Emergency Management Department. It is assumed that these same storms affected eastern Massachusetts, including Concord.

Fire-Related Hazards

Brush fires and drought fall under the category of fire-related natural hazards.

According to the State Plan, the most recent severe drought in the state occurred from 2001 to 2003 and other multi-year droughts occurred in 1879-83, 1908-12 , 1929-32, 1939-44, 1961-69, and 1980- 83.

Recent wild fires in the state, according to the state plan, affected 2,600 acres in 2002, and 1,600 acres in 2003. Approximately 90% of wild fires in the past 10 years were caused by humans and 10% by lightning. In addition to obvious threats to humans and property, because wildfires burn ground vegetation and ground cover, subsequent rains can worsen erosion.

According to local officials, natural fires in Concord are not a significant issue. The town sees a handful of brush fires annually, but these fires do not usually cause property damage or injuries. It is important, however, to remember that fire can also be a result of other events such as from the aftermath of an earthquake.

Geologic Hazards

Geologic hazards include earthquakes, landslides, sinkholes, subsidence, and unstable soils such as fill, peat and clay.

Earthquakes

According to the State Hazard Mitigation Plan, New England experiences an average of five earthquakes per year. From 1627 to 1989, 316 earthquakes were recorded in Massachusetts. Most have originated from the La Malbaie fault in Quebec or from the Cape Anne fault located off the coast of Rockport. The region has experienced larger earthquakes, of magnitude 6.0 to 6.5 in 1727 and 1755. Other notable earthquakes occurred here in 1638 and 1663 (Tufts University).

As shown on Map 4 in Appendix A, no earthquake epicenters have been recorded within Concord. Although new construction under the most recent building codes generally will be built to seismic standards, much of the development in the town pre-dates the most recent building code.

Earthquakes can result in many impacts beyond the obvious structural impacts. Buildings may suffer structural damage that is not readily apparent. Earthquakes can cause major damage to roadways, making emergency response difficult. Water lines and gas lines can break, causing flooding and fires. Equipment in buildings can be vulnerable. For example, a hospital may be structurally engineered to withstand an

earthquake, but if the equipment inside the building is not properly secured, the operations at the hospital could be severely impacted during an earthquake. Earthquakes can also trigger landslides.

The State Plan includes a map of Peak Ground Acceleration (PGA). The Plan explains that:

> "PGA measures the strength of a potential earthquake in terms of the peak acceleration of ground movement. The potential damages due to an earthquake increase as the acceleration of ground movement increases. Peak ground acceleration is expressed as a percentage of a known acceleration, the acceleration of gravity…Therefore, the geographic areas with the highest PGA have the highest potential for damages during an earthquake."

According to the State Plan, Concord is located in a section of the state with a PGA of 14 to 16 with a 2% probability of exceedance in 50 years; this is the third/fourth highest zone in the state.

Landslides

Landslides can result from human activities that destabilize an area or can occur as a secondary impact from another natural hazard such as flooding. In addition to structural damage to buildings and the blockage of transportation corridors, landslides can lead to sedimentation of water bodies.

The eastern half of Concord is classified as having a moderate risk for landslides, while the western half is classified as low risk. Local officials did not identify any significant issues related to landslides.

Overarching Impacts from Natural Hazards

A number of impacts can occur from any of the above-mentioned natural hazards. Most common and most visible are electrical outages and closures of roadways. This can occur due to high winds that knock down wires and limbs, from heavy snow falls that take time to clear, or from a landslide that carries large boulders or soil onto a roadway. In addition to causing inconveniences, these impacts can result in economic losses to local businesses that cannot function without electricity, or their customers or employees cannot get to the business. Minimizing vulnerability to natural hazards can help to reduce these and other impacts to people's safety, health, and overall economic viability.

Critical Facilities Infrastructure in Hazard Areas

Maps 1-7 in Appendix A and Table 9 list critical infrastructure in Concord. Critical infrastructure includes those facilities that perform an important function during a natural disaster such as shelters and emergency operation centers. Critical infrastructure also includes locations that house sensitive populations, such as schools or nursing homes. There are other critical facilities and infrastructure that may not be mapped because the information was not available. These may include utilities, communication facilities, or transportation corridors. The purpose of mapping the natural hazards and critical facilities is to present an overview of hazards in the community and how they relate to critical facilities.

Much of the Critical infrastructure in Concord is clustered near the center of town and clustered in West Concord. Both of these clusters are located in or near floodplain areas. Specifically, six facilities are located in the 500-year FEMA floodplain (X500), and 20 facilities are located within the 100-year floodplain (AE). 27 facilities are located within locally-identified areas of flooding.

Landslide risks within the town are either low or moderate, and the table below indicates which sites fall into either of those categories.

The entire town has snow accumulation averages of 48-72 inches and therefore all critical facilities fall within this category. This also holds true for average wind speeds, which are uniform at 110 mph throughout the town.

Critical sites the town staff has emphasized that are particularly important and vulnerable include:

- Underground Storage Tanks (USTs) in or near flooding areas
- Sewer pump stations in or near flooding areas (such as the Lowell Road wastewater pump station and the Main Street Pump station)
- Fire Station / Police station vulnerable to earthquakes
- State Police barracks, state land with USTs, and the state prison
- All bridges along Route 2 are critical assets for evacuation
- All bridges, particularly ones with weight restrictions that require detours
- Oil terminal in floodplain near Concord Center

The breakdown of the critical sites and how they relate to selected hazards follows in Table 9.

Table 9: Relationship of Critical Facilities and Selected Hazard Types in Concord

ID	Name	Type	FEMA Flood Zone	Locally-Identified Flood Area	Landslide Risk
1	Concord Carlisle Regional High School	School	No	No	Moderate
2	Emerson Hospital	Hospital	No	No	Low
3	Alcott School	School	No	No	Moderate
4	Thoreau School	School	No	No	Low
5	Willard School	School	No	No	Moderate
6	Middle School	School	No	No	Low
7	Middle School	School	No	No	Low
8	Concord-Carlisle Regional	School	No	No	Moderate
9	Concord Academy	School	No	Concord Center	Moderate
10	Fenn School	School	No	No	Moderate
11	Nashoba Brooks School	School	No	No	Low
12	Middlesex School	School	No	No	Low
13	Rivercrest Deaconess	Nursing Home	No	No	Low
14	Walden Rehabilitation and Nursing Center	Nursing Home	No	No	Low
15	CVS	Pharmacy	No	No	Moderate
16	Brooks Pharmacy	Pharmacy	No	Concord Center	Moderate
17	West Concord Pharmacy	Pharmacy	No	No	Low
18	Congregation Kerem Shalom	Place of Assembly	No	No	Low
19	Redeemer Presbyterian Church	Place of Assembly	No	No	Moderate
20	First Church of Christ	Place of Assembly	No	Concord Center	Moderate
21	First Parish in Concord	Place of Assembly	No	Concord Center	Moderate
22	New Life Community Church	Place of Assembly	No	No	Moderate
23	Holy Family Parish	Place of Assembly	No	Concord Center	Moderate
24	Trinitarian Congregational Church	Place of Assembly	No	Concord Center	Moderate
25	Trinity Episcopal Church	Place of Assembly	No	No	Moderate
26	West Concord Union Church	Place of Assembly	No	No	Low
27	Concord Municipal Light Plant	Place of Assembly	No	No	Low
28	Concord Public Works	Department of Public Works	X500	Concord Center	Moderate

ID	Name	Type	FEMA Flood Zone	Locally-Identified Flood Area	Landslide Risk
29	Concord Town House	Town Hall	No	Concord Center	Moderate
30	Concord Planning & Land Management	Municipal	AE	Concord Center	Moderate
31	Concord Police Department	Police	AE	Police/Fire Station	Moderate
32	State Police Concord	Police	No	No	Low
33	Concord Fire Department	Fire	No	No	Low
34	Concord Fire Department	Fire	AE	Police/Fire Station	Moderate
35	A Place to Grow at Concord Day Care	Daycare	No	No	Moderate
36	Day Care	Daycare	No	No	Moderate
37	Concord Carousel Day Care	Daycare	No	No	Low
38	Concord Children's Center #1	Daycare	No	No	Low
39	Concord Children's Center #2	Daycare	No	No	Moderate
40	Concord Children's Center #3	Daycare	No	No	Low
41	Concord Recreation After School Program	Daycare	No	No	Low
42	Holt-Tuttle, Diane F. Day Care	Daycare	No	No	Moderate
43	LEAP School at Concord	Daycare	No	Concord Center	Moderate
44	Milldam Nursery School	Daycare	No	Concord Center	Moderate
45	Minute Man ARC for Human Services, Inc.	Daycare	X500	No	Low
46	Simpson, Phyllis E. Day Care	Daycare	No	No	Low
47	The Barn Coop Nursery School	Daycare	No	Concord Center	Moderate
48	The Children's Meetinghouse Day Care	Daycare	No	No	Low
49	Umina, Catherine Day Care	Daycare	No	No	Low
50	MCI - Concord	Correctional Facility	No	No	Low
51	Northeastern Correctional Center	Correctional Facility	No	No	Low
52	Walden Street School for Girls	School	No	No	Moderate
53	Annursnac Hill Tower	Communicatio n	No	No	Low
54	Annursnac Hill Repeater Tower	Repeater Tower	No	No	Low
55	Annursnac Hill Water	Water Tank	No	No	Low

ID	Name	Type	FEMA Flood Zone	Locally-Identified Flood Area	Landslide Risk
	Tank				
56	Concord District Court	Courthouse	AE	No	Moderate
57	Hugh Cargill Water Pump Station	Water Pumping Station	No	No	Moderate
58	Robinson Water Pump Station	Water Pumping Station	No	No	Moderate
59	Robinson Public Well	Well	AE	No	Moderate
62	Second Division Water Pump Station	Water Pumping Station	No	No	Low
63	White Pond Water Pump Station	Water Pumping Station	No	No	Moderate
64	Jennie Duggan Water Pump Station	Water Pumping Station	No	No	Low
65	Deaconess Water Pump Station	Water Pumping Station	X500	No	Low
67	Concord Wastewater Treatment Facility	Wastewater Treatment Plant	No	No	Moderate
68	Bedford Street Sewer Pump Station	Wastewater Pump Station	No	No	Moderate
69	Lowell Road Sewer Pump Station	Sewer Pumping Station	AE	Lowell Road Sewer Pump Station / Concord Center	Moderate
70	Concord Water/Sewer/Highway Department	Municipal	X500	Concord Center	Moderate
71	Laurel Street Sewer Pump Station	Sewer Pumping Station	AE	No	Moderate
72	Assabett Sewer Pump Station	Sewer Pumping Station	No	No	Low
73	Cousins Park Sewer Pump Station	Sewer Pumping Station	No	No	Low
74	Park Lane Sewer Pump Station	Sewer Pumping Station	X500	No	Low
75	Pilgrim Road Sewer Pump Station	Sewer Pumping Station	No	No	Moderate
76	Gifford Land Sewer Pump Station	Sewer Pumping Station	No	No	Low

ID	Name	Type	FEMA Flood Zone	Locally-Identified Flood Area	Landslide Risk
77	Harvey Wheeler Community Center	Place of Assembly	No	No	Low
78	Concord Health Care	Nursing Home	No	No	Low
79	Mobil Gas Station	HazMat	No	Cambridge Turnpike	Moderate
80	Sudbury Road Mobil Gas Station	HazMat	No	No	Moderate
81	Cumberland Farm Gas Station	HazMat	No	No	Moderate
82	Commonwealth Avenue Gulf Gas Station	HazMat	No	No	Low
83	Colonial Motors Gas Station	HazMat	No	No	Low
84	Gas Station	HazMat	No	No	Moderate
85	Main Street Mobil	HazMat	No	No	Low
86	Concord Oil Company	HazMat	AE	Concord Center	Moderate
87	Exxon Gas Station	HazMat	No	No	Low
88	Citco Gas Station	Gas Station	AE	Concord Center	Moderate
89	Volunteers of America Assisted Living	Assisted Living	No	No	Low
90	Warners Pond Dam	Dam	AE	No	Low
91	Kennedy's Pond Dam	Dam	No	Harrington Avenue	Low
92	Damondale Dam	Dam	AE	No	Low
93	Harrington Ave Dam	Dam	AE	Harrington Avenue	Low
94	Lower Musquetaquid Pond Dam	Dam	No	No	Low
95	Upper Musquetaquid Pond Dam	Dam	No	No	Low
96	Batemans Pond Dam	Dam	No	No	Low
97	Barretts Mill Road Dam	Dam	A	Barretts Mill Road east of Strawberry Hill Road	Low
98	Dakin Brook Dam	Dam	AE	No	Low
99	Crosby Brook Dam	Dam	AE	Crosby Pond	Moderate
100	Pine Street Bridge	Town-Owned Bridge	AE	Pine Street Bridge	Low
101	Sudbury Road - Heath's Bridge	Town-Owned Bridge	AE	Sudbury Road - Heath's Bridge	Moderate
102	Nashawtuc Road - Nashawtuc Bridge	Town-Owned Bridge	X500	Nashawtuc Road	Moderate
103	Monument Street - Flint's Bridge	Town-Owned Bridge	AE	No	Moderate
104	Main Street Bridge between Elm and Wood	State-Owned Bridge	AE	No	Moderate

ID	Name	Type	FEMA Flood Zone	Locally-Identified Flood Area	Landslide Risk
105	Route 2 Bridge over Sudbury River	State-Owned Bridge	AE	Route 2 Bridge over Sudbury River	Moderate
106	Main Street Bridge near Derby	State-Owned Bridge	AE	No	Low

Explanation of Columns in Table 9

Column 1: ID #: ID number which appears on the maps. See Appendix A.

Column 2: Site Name: Name of the site. If no name appears in this column, this information was not provided to MAPC by the community.

Column 3: Site Type: Type of site.

Column 4: FEMA Flood Zone: Risk of flooding. No entry in this column means that the site is not within any of the mapped risk zones on the Flood Insurance Rate Maps (FIRM). If there is an entry in this column, it indicates the type of flood zone as follows:

Zone A - Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs (base flood elevations) or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone AE and A1-A30 - Zones AE and A1-A30 are the flood insurance rate zones that correspond to the 100-year floodplains that are determined in the FIS by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Zones B, C, and X500 - Zones B, C, and X are the flood insurance rate zones that correspond to areas outside of the 100-year floodplains, areas of 100-year sheet flow flooding where average depths are less than 1 foot, areas of 100-year stream flooding where the contributing drainage area is less than 1 square mile, or areas protected from the 100-year flood by levees. No BFEs or depths are shown within this zone.

Zone VE - Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply

Column 5: Locally-Identified Flood Area: Whether the site is located within an area that was identified by town officials and staff as a localized area of flooding. These areas may or may correspond with FEMA flood zones.

Column 6: Landslide Risk: The degree of landslide risk for that site. This information came from NESEC. The landslide information shows areas with moderate susceptibility to landslides based on mapping of geological formations. This mapping is highly general in nature. For more information, refer to http://pubs.usgs.gov/pp/p1183/pp1183.html. If there is no entry, it indicates that the site is located in an area with little or no risk of landslides. The other two risk categories, low and moderate, indicate higher degrees of risk.

Potential Damages to Existing Development

The purpose of the vulnerability assessment is to estimate the extent of potential damages from natural hazards of varying types and intensities. A vulnerability assessment and estimation of damages was performed for hurricanes, earthquakes and flooding. The methodology used for hurricanes and earthquakes was the HAZUS-MH software. The methodology for flooding was developed specifically to address the issue in many of the communities where flooding was not solely related to location within a floodplain.

Introduction to HAZUS-MH

HAZUS-MH is a tool to help estimate potential damages from certain types of natural hazards. We used HAZUS to estimate losses from a hurricane and earthquake. We did not use HAZUS to estimate flooding damages, for reasons explained below. The following overview of the HAZUS-MH is taken from the FEMA website. For more information, go to http://www.fema.gov/plan/prevent/hazus/.

> "HAZUS-MH is a nationally applicable standardized methodology and software program that contains models for estimating potential losses from earthquakes, floods, and hurricane winds. HAZUS-MH was developed by the Federal Emergency Management Agency (FEMA) under contract with the National Institute of Building Sciences (NIBS). Loss estimates produced by HAZUS-MH are based on current scientific and engineering knowledge of the effects of hurricane winds, floods and earthquakes. Estimating losses is essential to decision-making at all levels of government, providing a basis for developing and evaluating mitigation plans and policies as well as emergency preparedness, response and recovery planning.
>
> HAZUS-MH uses state-of-the-art geographic information system (GIS) software to map and display and display hazard data and the results of damage and economic loss estimates for buildings and infrastructure. It also allows users to estimate the impacts of hurricane winds, floods and earthquakes on populations."

There are three modules included with the HAZUS-MH software: hurricane wind, flooding, and earthquakes. There are also three levels at which HAZUS-MH can be run. Level 1 uses national baseline data and is the quickest way to begin the risk assessment process. The analysis that follows was completed using Level 1 data.

Level 1 relies upon default data on building types, utilities, transportation, etc. from national databases as well as census data. While the databases include a wealth of information on the communities that are a part of this study, it does not capture all relevant information. In fact, the HAZUS training manual notes that the default data is "subject to a great deal of uncertainty."

However, for the purposes of this plan, the analysis is useful. This plan is attempting to only generally indicate the possible extent of damages due to certain types of natural

disasters and allow for a comparison between different types of disasters. Therefore, this analysis should be considered a starting point to understanding potential damage from the hazard events. If interested, communities could build a more accurate database and further test disaster scenarios.

Table 10 displays damages from category 2 and 4 hurricanes. Table 11 displays damages if an historic earthquake were to occur today and if a stronger (7.0) earthquake were to occur.

Estimated Damages from Hurricanes

According to the State Hazard Mitigation Plan, between 1858 and 2000, there were 15 hurricanes: 60% were Category 1, 33% were Category 2 and 7% were Category 3. For the purposes of this plan a Category 2 and a Category 4 storms were chosen to illustrate damages. While the region has not experienced a Category 4 hurricane, modeling one helps to illustrate a "worst case scenario." This can help planners and emergency personnel evaluate the impacts of storms that might be more likely in the future, as we enter into a period of more intense and frequent storms.

Table 10. Estimated Damage in Concord from a Category 2 or 4 Hurricane

	Cat. 2	Cat 4*
Building Characteristics		
Estimated total buildings	5,513	
Estimated total building replacement value (Year 2002 $)	$1,396,227,000	
General Building Damage		
# of buildings sustaining minor damage	1,863	221
# of buildings sustaining moderate damage	665	805
# of buildings sustaining severe damage	97	1,539
# of buildings destroyed	70	2,928
Population Needs		
% of hospital beds available on day of event	0	0
# of households displaced	151	5,151
# of people seeking public shelter	29	981
Debris		
Building debris generated	11,161	158,109
Tree debris generated	215,212	423,267
# of truckloads to clear building debris	446	6,324
Value of Damages		
Total property damage	$98,031,260	$1,474,326,310
Total business interruption loss	$12,445,520	$210,003,510

*No category 4 or 5 hurricanes have been recorded in New England. However, a Category 4 hurricane was included to help the communities understand the impacts of a hurricane beyond what has historically occurred in New England.

Estimated Damages from Earthquakes

The HAZUS earthquake module allows users to define different types of earthquakes and to input various parameters. The module is more useful where there is a great deal of data available on earthquakes. In New England, defining the parameters of a potential earthquake is much more difficult because there is little historical data. The earthquake module does offer the user the opportunity to select a number of historical earthquakes that occurred in Massachusetts. For the purposes of this plan, two earthquakes were selected: a 1963 earthquake with a magnitude of 5.0 and an earthquake with a magnitude of 7.0.

Table 11: Estimated Damage in Concord from a Magnitude 5.0 and 7.0 Earthquake

	Magnitude 5.0	Magnitude 7.0
Building Characteristics		
Estimated total number of buildings	5,513	
Estimated total building replacement value (Year 2002 $)	$1,396,227,000	
Building Damages		
# of buildings sustaining slight damage	10	1,247
# of buildings sustaining moderate damage	2	437
# of buildings sustaining extensive damage	0	73
# of buildings completely damaged	0	12
Population Needs		
# of households displaced	0	63
# of people seeking public shelter	0	11
Debris		
Building debris generated (tons)	0	26,000
# of truckloads to clear building debris	0	1,040
Value of Damages		
Total property damage	$390,000	$62,610,000
Total losses due to business interruption	$30,000	$12,420,000

Estimated Damages from Flooding

MAPC did not use HAZUS-MH to estimate flood damages in Concord. In addition to technical difficulties with the software, the riverine module is not a reliable indicator of flooding in areas where inadequate drainage systems, beaver activity, and increased impervious surfaces contribute to flooding even in areas outside of mapped flood zones. In lieu of using HAZUS, MAPC developed a methodology to give a rough approximation of flood damages.

Approximately 487 acres of Concord's total land area of 16,532 acres have been identified by local officials as areas of flooding. This amounts to 2.94% of the land area. The number of structures in each flood area was estimated by applying the percentage of the total land area to the total number of structures (5,513) in Concord, which is the same number of structures used by HAZUS for the hurricane and earthquake calculations. HAZUS uses an average value of $253,260 per structure for the building replacement value in this community. The calculations were done for a low estimate of 10% building damages and a high estimate of 50% as suggested in the FEMA September 2002

publication, "State and Local Mitigation Planning how-to guides" (Page 4-13). The range of estimates for flood damages is $4,482,700 - $22,413,500. These calculations are approximate only and are meant to show an order of magnitude of damage. These calculations are not based solely on location within the floodplain or a particular type of storm (i.e. 100 year flood).

Table 12: Estimated Damages from Flooding in Concord

ID	Flood Hazard Area	Approx Area (Acres)	% of Total Land Area in Concord	# of Struct.	Replacement Value	Low Estimate of Damages	High Estimate of Damages
1	Westvale Meadows Condominiums	7.15	0.043%	3	$759,780	$75,978	$379,890
2	Pine Street Bridge	0.46	0.003%	1	$253,260	$25,326	$126,630
3	Commonwealth Avenue at Warners Pond	7.47	0.045%	3	$759,780	$75,978	$379,890
4	Pedestrian Bride at Warners Pond	0.62	0.004%	1	$253,260	$25,326	$126,630
5	Spencer Brook Bridge	9.14	0.055%	4	$1,013,040	$101,304	$506,520
6	Sudbury Road - Heath's Bridge	38.92	0.235%	13	$3,292,380	$329,238	$1,646,190
7	Fitchburg Turnpike	48.90	0.296%	17	$4,305,420	$430,542	$2,152,710
8	Route 2 Bridge over Subdury River	6.23	0.038%	3	$759,780	$75,978	$379,890
9	Concord Center	174.17	1.054%	59	$14,942,340	$1,494,234	$7,471,170
10	Cambridge Turnpike	90.15	0.545%	31	$7,851,060	$785,106	$3,925,530
11	Hawthorne Lane	21.49	0.130%	8	$2,026,080	$202,608	$1,013,040
12	Police/Fire Station	8.18	0.049%	3	$759,780	$75,978	$379,890
13	Harrington Avenue	7.31	0.044%	3	$759,780	$75,978	$379,890
14	Laws Brook Road	2.89	0.017%	1	$253,260	$25,326	$126,630
15	Lowell Road Sewer Pump Station	1.42	0.009%	1	$253,260	$25,326	$126,630
16	Williams Road	6.57	0.040%	3	$759,780	$75,978	$379,890
17	Barretts Mill Road	6.98	0.042%	3	$759,780	$75,978	$379,890
18	Barretts Mill Road east of Strawberry Hill Road	11.65	0.070%	4	$1,013,040	$101,304	$506,520
19	Old Road to Nine Acres Corner	2.91	0.018%	1	$253,260	$25,326	$126,630
20	Heaths Bridge Road	4.11	0.025%	2	$506,520	$50,652	$253,260
21	Nashawtuc Road	3.72	0.022%	2	$506,520	$50,652	$253,260
22	Liberty Street	4.05	0.025%	2	$506,520	$50,652	$253,260
23	Peters Spring Road	4.65	0.028%	2	$506,520	$50,652	$253,260
24	Crosby Pond	11.38	0.069%	4	$1,013,040	$101,304	$506,520
25	Virginia Road	2.39	0.014%	1	$253,260	$25,326	$126,630
27	Main Street Bridge between Elm and Wood	3.77	0.023%	2	$506,520	$50,652	$253,260
	Total	**486.72**	**2.94%**	**177**	**$44,827,020**	**$4,482,702**	**$22,413,510**

Potential Impacts to Future Development

The Town of Concord has identified a number of parcels where development has been proposed, is underway or is expected to occur in the future. Table 13 indicates where areas of likely future development may be located within or partially within a natural hazard area.

Table 13: Relationship of Potential Development in Hazard Areas in Concord

Parcel	Land Slide Risk	Flood Zone
Alexan Concord 40B (350 units)	low	No
Forest Ridge Road Residential Development (200 units)	low	No
Commerford Road Residential Development (40 - 60 units)	low	No
Strawberry Hill Road Residential Development (20 units)	low	No
Emerson Hospital Expansion	low	No
New England Deaconess Expansion (30 units)	low	9.54% in X500, 4.95% in AE